

# Investigation of non linear magnetoelastic effects under variable stress field and temperature

**Personnel:** D.C. Jiles (Senior Physicist), L.Li (Graduate student) , J.M.Kenkel (Student), S.J.Lee (Postdoctoral Fellow), C.C.H. Lo (Associate Scientist) and S.B.Biner (Scientist).

## Abstract:

In order to formulate a consistent predictive theory describing, and therefore helping to understand magnetic phenomena at various length scales, it is necessary to describe physical interactions that operate over spatial scales from atomistic to macroscopic, and temporal scales that vary over at least eight orders of magnitude. Mathematical model theories have therefore been developed and tested to describe non-linear magnetization and magnetomechanical effects.

## Recent Results:

Development of an integrated magnetic material property modeling software has recently been completed. The capabilities of this software include ferromagnetic hysteresis, magnetomechanical and magnetoelastic effects, spin relaxation effects and Barkhausen effect. It also includes the 1-, 2-, and 3- dimensional equations for description of texture effects and anhysteretic magnetizations in a variety of situations. The model allows a wide range of magnetic property simulations to be made using a single program in which the equations and algorithms are based on underlying physical principles of the magnetization and magnetostriction processes.

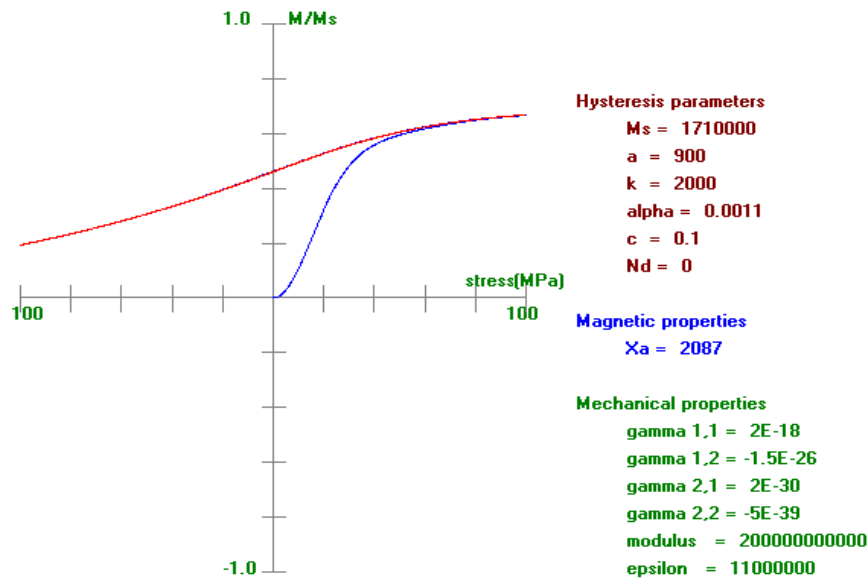


Fig. 1. Macroscopic model calculations using modified “law of approach” which includes a linear term in addition to the usual quadratic term relating energy to stress

In addition, a finite element modeling (FEM) code has been expanded to include non-linear cases where magnetic hysteresis can be accurately described. To achieve this, existing analytical models were incorporated and their computational efficiency and accuracy were studied to determine suitability for incorporation into the program. Computationally efficient FEM modeling requires large-scale computations to accommodate the effects of geometry and

boundaries, even in the absence of material non-linearity. Also, in many magnetic field analysis problems, the field of influence extends theoretically to infinity, although the domain of interest is usually bounded. The standard FEM analyses are extremely inefficient for modeling unspecified boundary value problems. To eliminate this deficiency, we have developed software based on “infinite” elements that can be used in conjunction with our FEM code.

- Time = 5 ns
- $H_{\text{app}} = 10^3 \text{ A/m}$
- Stress =  $-10^9 \text{ Pa}$
- $\alpha = 0 \text{ m}^{-3}$
- $K1 = 0 \text{ J/m}^3$

light moments have component pointing down into the plane

dark moments have component pointing up out of the plane

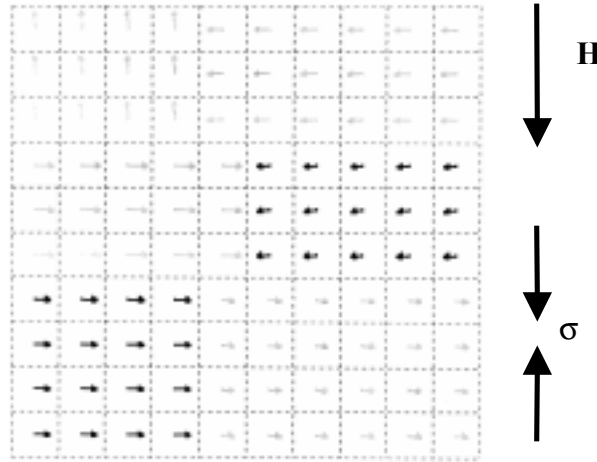


Fig.2. Atomistic scale calculations using the Landau-Lifschitz-Gilbert equation modified to include the effect of applied stress, incorporated into the main equation as a contribution to the effective field via the magnetoelastic coupling. Compressive stress  $\sigma$  along the vertical axis causes the magnetic moments to prefer to align perpendicular to a weak magnetic field  $H$

#### Significance:

This work is exploring the fundamental basis for describing the response of materials to high levels of external magnetic field in regimes where the standard linear response approximations are no longer valid.

#### Future Work:

Efforts continue toward developing fully three-dimensional, non-linear magnetic models for describing the magnetic properties of materials. These models will be essential to the understanding of these properties from the atomistic to the macroscopic scales.

#### Interactions:

M.J.Sablik, Southwest Research Institute, San Antonio, Texas, K.Metlov, Czech Academy of Sciences, Prague, Czech Republic, W. A. Theiner, Fraunhofer Gesellschaft, University of the Saarland, Germany.